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ABSTRACT

As the applications of computing have expanded, the issues of computing and higher education have enlarged to include questions about the nature of information transfer on campus and the role of higher education in an information society. A broad view of the national issues and opportunities of computing in higher education is presented. A panel of educators and industrialists took part in developing a consensus statement of issues and recommendations. The recommendations are set against these background issues: (1) other countries are developing highly integrated plans for accelerating the transition to information-based economies through joint efforts of industry, government, and education; (2) increased productivity and trade will be closely linked to our ability to apply the results of new developments in microelectronics, computing, and communications; (3) the United States faces a critical shortage of people educated to use computers, and higher education faces severe resource problems of faculty and facilities in responding to national needs; and (4) concern for these issues and support for the development of strategies to improve our national position have been shown by those in industry, government, and education. The principal recommendation is to develop cooperative programs to work with professional, industrial, governmental, and educational groups to support higher education computing, and that a commission to initiate these activities be established through the National Science Board. (MSE)

Computing and Higher Education: an Accidental Revolution

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But the principal failing occurred in the sailing,
And the Bellman, perplexed and distressed,
Said he *had* hoped, at least, when the wind blew due East,
That the ship would *not* travel due West!

—Lewis Carroll, *The Hunting of the Snark*

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CONSENSUS PANEL MEMBERS

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SUMMARY

As the applications of computing have expanded from calculating to information processing, the issues of computing and higher education have enlarged to include questions about the nature of information transfer on campus and about the role of higher education in an information society. Computing has been a catalyst for accelerating the nation's transition to an information economy in which over half of the GNP comes from information-related activities. This information-based economy facilitates new ways to produce, store, retrieve, and transfer information. These changes in how we communicate are transforming the nation into an information society. The transition has been extremely rapid, and because it has been largely unplanned, with continual new unexpected developments, it is an accidental revolution.

Higher education in particular has been slow to respond to the challenges and opportunities of rapid technological change. Over 2% of the higher education budget is devoted to computing, but because more than half of these funds are for administrative applications, there is still relatively little funding for instructional applications. Yet new technological developments will soon put personal computers within the reach of every student. The cost of a microprocessor/terminal/typewriter will be equivalent to the price of six books, or of a slide rule in the 1960's. Parents throughout the United States are showing their interest in the new educational possibilities by purchasing home computers, and in some cases are outdistancing the concern of the educational establishment by using PTSA's to raise money to place microprocessors in high schools.

This report presents a broad view of the national issues and opportunities of computing in higher education. In the 1960's, the last time a study of this nature was undertaken, the national issues were how to introduce the new tool—the computer—into research and instruction and how to improve access through networking. The problems for the 1980's will require a broader approach to consider how to integrate the traditional roles of higher education into the new "information marketplace" and how to link the interests of education, industry, and government in efforts to improve national productivity.

A panel of educators and industrialists played a major role in developing a consensus statement of the issues and the recommendations for action which form the conclusion of the report. The primary recommendation is to develop cooperative programs to work with professional, industrial, government, and educational groups in order to support computing in higher education. The panel recommended that a commission to initiate these activities be established through the National Science Board.

American education and science play critical roles in meeting national needs, and will be important in aiding the transformation to an information society. The recommendations of this report to improve computing in higher education are set against these background issues:

- Other nations are developing highly integrated plans for accelerating their transition to information-based economies through joint efforts of industry, government, and education.

- Increased productivity and trade will be closely linked to our ability to apply the results of new developments in microelectronics, computing, and communications.

• The United States faces a critical shortage of people educated to use these new tools, and in turn, higher education faces severe resource problems (faculty and facilities) in responding to these national needs.

• Concern for these issues, and support for the development of strategies to improve our national position, have been shown by those in industry, government, and education.

1. INTRODUCTION AND FINDINGS

"After growing wildly for years, the field of computing now appears to be approaching its infancy."

Pierce Report, 1967

The field of computing continues to grow wildly, and is still approaching infancy. When the Pierce Report[1] was written in 1967, about $200 million was being spent annually on computing in higher education; over $1 billion annually is being spent today. The percentage of colleges and universities with either their own computers or access to them has grown from 10% to 90% in the last 15 years. It would seem that we have achieved the goals set in the Pierce Report for remedying the deficit in computing education so that "No American need have second-rate education in this respect."

Or have we?

The fastest growing segment of computing in higher education is not instruction, not research, but administration. Over half of the current expenditures are for administrative services. The funds spent on instructional computing are approximately $20 per student per year. The Pierce Report estimated that about 30 hours per year of interactive computing were required for undergraduate use (averaged over all students). Currently, use of midi computers (considering all costs) can be provided for $2-$3 per terminal hour, meaning that the current $20 per student could provide 10 hours of use per year, or one-third of what the Pierce Report recommended nearly 15 years ago. Thus, we are not yet near achieving the goals set in the Pierce Report for instructional use. These goals still seem appropriate when we examine the current use at schools such as Dartmouth and Carnegie-Mellon which have the commitment to, and the facilities for, interactive computing.

1.1 New Issues That Have Developed Since the Pierce Report

(1) Computing not only calculates but transforms information. Traditionally computers have been used in education as research tools, subjects of study, and vehicles for training students in computing languages. These applications are rapidly broadening so that computers are used to:

(a) Aid in instruction (computer-aided instruction and computer-based education);

(b) Edit text and process publications;

(c) Access libraries and data bases;

(d) Communicate messages (electronic mail).

These new opportunities provide additional capabilities in accomplishing intellectual tasks. Thus we have added new tools to the traditional pen and pencil, typewriter, and telephone.

1. President's Science Advisory Committee, *Computers in Higher Education* (Pierce Report). The report assessed the needs of computing in higher education and warned that growth in interactive computing would require significant resources.

The next stages of computer use will have new and qualitatively different effects that will ripple through the frameworks of existing institutions causing controversy and competition for already tight resources. Opportunities for diversifying the educational process will arise as we develop new and more productive instructional techniques through the confluence of computing, communications, and video disk technology. Already we see a large growth taking place in education outside of traditional institutions. Today over ten billion dollars is spent each year on continuing education (seminars, training).

(2) The revolution in computer power (25% per year gains in performance for the past 15 years) continues to create options for new applications. Each student will soon be able to afford his or her own microprocessor/terminal. The market for home computers in the U.S. has grown from zero five years ago to over 300,000 units per year today. Few secondary schools will be without units. PTSA's today are purchasing them for their students instead of football uniforms; this reflects new priorities in education.

(3) The current talent pool in higher education capable of meeting the needs for instruction and research in computing fails to meet our national needs by an order of magnitude. Reports from the National Science Foundation, the Bureau of Labor Statistics, and computer science groups indicate that this imbalance will continue to grow.[2] The table below shows the current estimate of the problem in computer science (not including engineering and other fields).

	AA	BA/BS	MS	Doctorate
GRADUATES	33,000	13,000	3,400	330
OPENINGS	26,000	54,000	34,000	1,300

Source: Hamblen, Computer Manpower—Supply and Demand—by States, p. 14.

Thus the major problem area exists above the associate level.

The deficit of teachers at these demand levels is exacerbated by the difficulty of retaining young faculty members due to the lure of high salaries and the availability of specialized computing facilities within industry. As Peter Denning, President of The Association for Computing Machinery has said, "We are killing the goose that laid the golden eggs."

(4) We must broaden the framework for discussion of computing to consider the current role of education in the transformation of the United States from an industrial to an information society. Following Machlup's description of "knowledge production," Marc Porat in 1977 completed an extensive study of the information industries

2. *Science and Engineering Education for the 1980's and Beyond*, National Science Foundation and the Department of Education; U.S. Bureau of Labor Statistics, *Occupational Projections and Training Data*, 1973 ed., Bulletin 2020, Washington: GPO, 1979; "Rejuvenating Experimental Computer Science: A Report to the National Science Foundation and Others," Jerome A. Feldman and William R. Sutherland eds.; "A Discipline in Crisis: A Report," Peter J. Denning ed.

and their importance to the U.S. economy.[3] He showed that the predominant occupational distribution has shifted in the last 100 years from farming to industry to information handling (Chart 1-1). Information processing has become the dominant national economic activity. Information activities (both direct and indirect) now account for over 46% of the Gross National Product, and over 50% of the labor income is now earned by information workers.

Information is the foundation of organizations and the essence of education. How information is gathered and stored, who has access to it, how it is used—all these affect the structure of an institution. Porat pointed out that the lines separating institutions are blurring due to the changes in the distribution processes:

> A banker, a newspaper publisher and the Postmaster General do not fancy themselves in the same business. Yet they are all information brokers specializing in the retail packaging and distribution of (unlike) information services. Function and form are converging, driven by a convergence of technologies.[4]

Business and industry are fast realizing that the computer is not a "computer" for calculating but a tool for information processing. New applications of these information tools (computers, communications, and software) reflect new opportunities to improve the productivity and efficiency of this segment of our economy, which in turn affects all other sectors.

These changes are leading to what has been called the "information society." Other nations have identified the links between education, computing, research, productivity, and the information society and are planning and investing to achieve new economic goals. The Japanese have an Information Society Plan, the French have a Plan "Telematique." The United States is just beginning to identify the roles of, and the relationships between, the different sectors in this transformation.

1.2 National Goals and Computing in Higher Education

The current shortage of computer scientists highlights the relationship between computing in higher education and national needs. Not only in computer science, but in all areas of training, research, and instruction, higher education contributes to national goals in productivity, trade, research, and citizen participation in society. As our economy becomes increasingly dependent on the production and distribution of information services the many roles which computing plays in higher education will become more important to our national welfare.

However, if computing is to make significant new contributions to educational and national goals, there are three problem areas with which we must deal:

Instruction

Technological innovation has created many new educational methods, but these must be carefully assessed in order to ensure that they increase productivity and that an environment conducive to their diffusion is provided. Also, there must be more incentives for individuals and organizations to develop instructional materials.

3. Marc Uri Porat, *The Information Economy.*

4. Porat, "Communication Policy in an Information Society," in *Communications for Tomorrow*, Glen O. Robinson ed., p. 28.

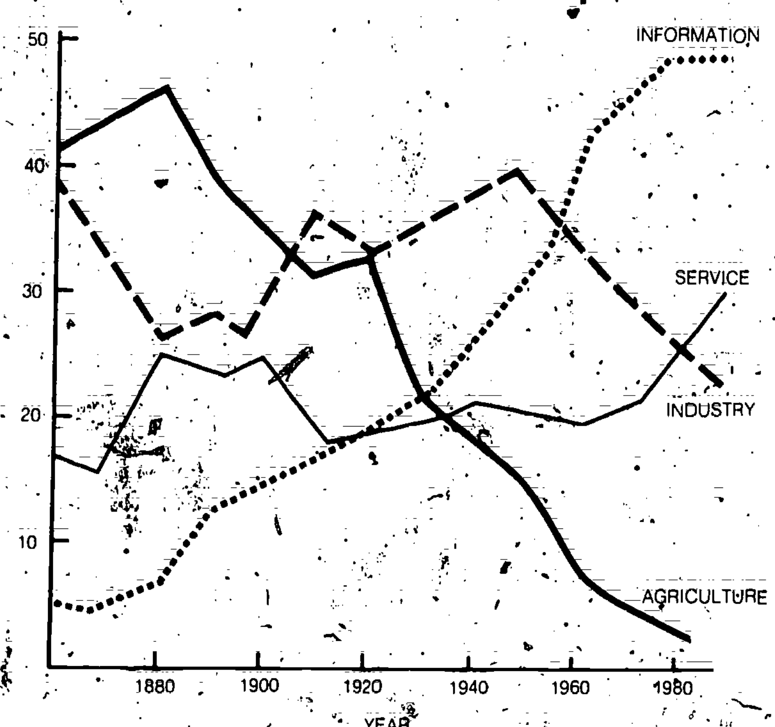
Resource Sharing

With the growing interdependence among educational institutions and among universities and industry, new strategies for resource sharing need to be developed. Capital investments must also be made for very large computing facilities, and access to these new tools must be provided.

Resource Conflicts

Although allocations for computing have grown significantly, and student population is remaining constant, the revolutionary growth in computing applications is causing severe problems in reallocating already-scarce resources to meet the needs for computer access. Institutions must assess their new needs and attempt new approaches for solving these problems.

Chart 1-1.
The Growth of Information Occupations
U.S. Work Force 1860–1980



Source: Porat, *The Information Economy*, Vol. I, p. 121

While information technologies are flourishing in business, industry, the professions, and the government, the field of education has yet to take full advantage of the new technologies. J. C. R. Licklider notes:

> Education is not only missing a great opportunity; it is failing to discharge a crucial responsibility. The world is rapidly moving into the "information age." In order to make the transition wisely and well, the public must understand information science and technology. People must master the technology or be mastered by it.[5]

1.3 Findings

The study's objective was to identify the national issues of computing and higher education.

The findings are:

(1) The nation is in the process of dramatic change in its economic and social framework from an industrial to an information society.

(2) Education has an important role in this transformation.

(3) Federal government intervention, through points at which research support or incentives will aid more rapid diffusion of computing techniques (and thus result in increased productivity, research, and trade), will be important.

(4) There are strong pressures which will push government, industry, and education into exploring new arrangements for productive relationships. Their individual roles are no longer so widely independent.

(5) Computing and information processes in universities will require planning and awareness by faculty, students, and administrators. Reallocation of already limited resources will continue to be necessary.

(6) The primary national issues for computing in higher education are:

- (a) Contribution to national goals
- (b) Public computer literacy/competency
- (c) Resource sharing and incentives for diffusion
- (d) Structural and organization changes in higher education
- (e) New options for instruction
- (f) Research support

1.4 The Accidental Revolution

Over 90% of the institutions of higher education have computer services (through their own computers or access to others' through terminals) available which are used in instruction, research, and administration. Today over 50% of the high schools in the country have computers, and with the rapid introduction of microprocessors and personal computers we can expect that by 1985 over three-fourths of high school students will have some experience with computing by the time they graduate.

This is an *accidental* rather than a planned revolution. College and university faculty and administrators are aware of the changes but unsure of what the revolution means to them. Should they expect to see gains in productivity? Will additional com-

5. J.C.R. Licklider, "Impact of Information Technology on Education in Science and Technology," in *Technology in Science Education*, p. 1.

puting improve quality (at additional costs!)? What are the incentives to develop instructional software? Who will evaluate it? How can schools share resources?

We have used the subtitle "Accidental Revolution" in order to emphasize the unplanned nature of the sweeping changes brought to higher education by the introduction of one of the first new intellectual tools since the printing press—the computer.

The revolution is accidental because the introduction of this new tool does more than improve the productivity of the existing process—it challenges the assumptions which we unconsciously make about the nature of work and learning. What will education be like in 1990 when terminals are portable and when computers, with the power found today in only large systems, are in each home? Will we be able to rethink the library—not as a repository for books but as a system for providing access to knowledge?

A popular phrase today is the "reindustrialization of the nation." But in order to "reindustrialize" we will need trained people and advanced research facilities to carry out the changes. Therefore, we must modernize our universities and colleges so that we can produce the talent—the intellectual capital—required for national growth.

2. APPROACH

2.1 Objectives and Beginnings

In 1977 when a simple growth model for interactive computing at the University of Washington showed that the academic computing budget would have to increase by a factor of five, we realized that there was a local problem.[1] After discussing the problem with a number of academic computer center directors at the annual Snowmass Conference, we realized that it was a national problem. Academic computing had embraced the goal of wide-spread interactive terminals for instruction and research but it was not prepared to deal with the costs of implementing that goal.

While discussing alternatives for confronting the resource issue we reviewed a number of past reports. These reports highlighted the *value* returned to the nation from the NSF capital investment program in the '60s which encouraged the introduction of computers into higher education by providing matching acquisition funds. The program, which had a significant impact on higher education, had these accomplishments:

(1) American research capabilities improved through the initial use of the new tool, the computer.
(2) Striking innovations in computing in universities led to major products (timesharing, networks, new architectures).
(3) Wide use of computers in higher education provided qualified graduates for industry and government.

The objective of this study became an analysis of the national goals and issues today. While there have been reviews of the contributions of, and opportunities for, computing in particular disciplines (for example, the Carnegie Commission study of instructional technology and the Feldman Report on Computer Science), there have been no recent efforts to examine the overall effect of computing and the interplay between the many computing applications.

Could we identify the opportunities today that would offer the same potential as the opportunities seized in the '60s?

2.2 The Steering Committee and Consensus Panel

A steering committee of people familiar with a variety of issues in computing and higher education and with special areas of expertise was formed to advise the principal investigator and to review both the strategy and the results of the investigation.

In addition, a Consensus Panel drawn from education and industry was convened to consider issues and recommendations for meeting national computing needs and to participate in developing this report. The panel issued a consensus statement and recommendations which are included as Appendix A.

The participants on the Steering Committee and Consensus Panel are listed at the front of this report.

1. This model was based on undergraduate use of three terminal hours/month and graduate and faculty use of six terminal hours/month (using Dartmouth estimates).

Chart 2-1. National Reports on Information Issues

REPORT	WHO STATES NATIONAL GOALS AND ISSUES	INSTRUCTION	NATIONAL NEEDS FOR COMPUTER COMPETENCY
COMPUTERS AND THE LEARNING SOCIETY	Presidential commission to investigate need for federal policies. Interim agency working group to coordinate research agenda. Executive Branch develop & implement research strategy.	Federal Govt. primary funding source for research on CBE to: 1) increase understanding at all levels 2) identify effective methods of dissemination 3) evaluate programs	
FEDERAL DATA PROCESSING REORGANIZATION PROJECT	Office of Information Resource Management in OMB. National Council for Information Technology Policy. Plans and Programs.		Upgrade training and career development.
REJUVENATING EXPERIMENTAL COMPUTER SCIENCE	Federal "lead agency" to promote computer science and computing.		
TECHNOLOGY IN SCIENCE EDUCATION THE NEXT TEN YEARS	Federal govt. to set telecommunications policy, undertake assessments to meet national needs.	Federal assistance in dissemination activities. Federal support for soft/courseware development. Federal introduction of microcomputers in schools	Mass media education on computer technology.
DIGITAL COMPUTER NEEDS IN COLLEGES AND UNIVERSITIES (ROSSER)			Increased training as users & experts.
COMPUTERS IN HIGHER EDUCATION (PIERCE)		Adequate computing to all students with govt sharing costs. Faculty training programs. Investigation of computer use in high schools, encourage cooperation.	Federal govt. to collect data on personnel, etc. Forecasts of needs.
CARNEGIE REPORTS FOURTH REVOLUTION AND FINAL REPORT		Commitment to expansion of technology. Develop outstanding instructional programs & materials. Federal support of R&D. Faculty incentives to develop materials. Teacher training. High school use. Commission to assess effectiveness and cost benefits.	
NATIONAL INFORMATION POLICY (ROCKEFELLER)	Office of Information Policy in Executive Branch. Coordinated national information policy		
SCIENCE AND ENGINEERING EDUCATION FOR THE 1980'S AND BEYOND	President's Council on Excellence in Science and Technology Education. National Conference to increase private sector commitment to excellence in education. Independent forum to address the relationships between federal government and the science and engineering education system.	Develop teaching materials in science and technology. Develop software to exploit modern technologies in education. Teacher training institutes	Greater public understanding of science and technology: adult education. Curricula in computer literacy

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RESEARCH	ADMINISTRATIVE COMPUTING	RESOURCE SHARING	STRUCTURAL AND ORGANIZATIONAL IMPACTS
A complete technology assessment of microcomputers.		Regional test and demonstration centers.	
OMB support of R&D ($25 million annual).	Establish measurements to evaluate products of information technology. Develop standards for information technology.	Improve service delivery through a national network. OMB support of national network for research efforts.	
Incentives to retain faculty & graduate students (e.g., career grants). Adequate experimental facilities (annual competitions). Joint university/industry research. Increased govt. funding.		Incentives to stimulate coupling between university & industry. Study programs within industrial labs. Exchange sabbaticals.	
Assessments of impacts of new technologies. Broad research on human learning.			
Government aid for computer science research. Coordination of research efforts.			Revised funding and auditing procedures.
Expand federal support of computer science research and education.	Accurate measurements of cost & utilization of computer services.	Govt. & university cooperation for establishment of large educational computing services.	Revise accounting practices to allow more educational use and freer applications of funds.
Federal support, especially for basic research.		Cooperative regional learning technology centers with federal funding.	First priority to libraries in introduction of new technologies. Develop extramural educational use of technologies. Basic reliance on the states, with coordination of new kinds of post secondary education. Federal support of educational innovation.
Post-graduate industrial traineeships. Federal support for purchasing research equipment in engineering and computer science. Incentives to enter university teaching.		Industry support for teacher-exchange programs. Regional centers to make equipment available to schools.	Reduce burdens of grant and contract management

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2.3 Definition of Issue Areas

(1) Literature Review

An extensive review of the literature on issues of computing and higher education led to the bibliography included as Appendix B. One of the principal objectives of the literature review was to identify previous efforts and recommendations dealing with national information and computing issues. Examples of previous reports and studies are shown in Chart 2-1.

(2) Survey

A survey instrument to assess community reaction to the statement of issues was widely distributed to groups concerned with higher education (including the Association for Computing Machinery—Special Interest Group for University Computer Centers, selected computer science department chairmen, and the Association for Educational Communications and Technology). The survey instrument is presented as Chart 2-2. The survey was arranged as seven questions identifying issue areas with potential programs.

(3) Visits To and Review of Other Countries

Visits were made to England, France, and Germany to investigate foreign approaches to the issues of computing and higher education and to determine the different national structures and approaches to the issues. The literature analyzing other national strategies was surveyed.

Chart 2-2. Survey Instrument

Issues and Opportunities:
Computing and Higher Education

As part of a National Science Foundation study of computing and higher education, we are attempting to identify the major issues and to formulate recommendations for dealing with these issues at the national level. A Steering Committee has agreed upon seven major areas and has suggested these programs for action.

Before a final report is made to NSF, we would like to achieve as wide a consensus as possible.

Please take a few minutes to write your reactions and comments on this worksheet. Are there issues which you feel important that are not covered?

Can you suggest programs for action?

Feel free to make copies and to distribute them to persons you think may be interested. You may return this worksheet (by refolding to address) to:

Robert G. Gillespie
Vice Provost for Computing
AG-75
University of Washington
Seattle, WA 98195

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1 Who can state the issues and develop strategy to achieve national goals?

- No office today is charged with displaying the issues, the data or the approaches that should be followed on the national level.
- Revolutionary changes are occurring in society, but there have been no coherent efforts to address the issues of technology and to articulate national policy towards increased productivity and opportunity.
- In particular, the critical problems and issues where computing and higher education affect achieving national goals have not been identified.
- The sectors of government, industry, and higher education (with its components of faculty, administration, etc.) will need clear roles and opportunities for interaction.

Possible Programs

- Establish a national commission with representatives from different groups (industry, education, government) to consider national issues and to support efforts to develop goals. Activities may include gaining large foundation support (Carnegie, Sloan, e.g.) and sponsoring reports, articles, PBS programs, etc. which address national issues of technology.
- Identify goals for government agencies, particularly the new Department of Education, NSF, and NAS which would be responsible for programs of action.
- Identify the possible roles and areas of interaction for the different sectors in developing programs to meet computing needs.

2 Instruction

- What is going to be taught to whom about computing, and at what level of instruction?
- We need more information and programs for assessing the usefulness of the new technologies and for integrating computing into the curriculum, both into the various disciplines and into general instruction on computers.
- With what incentives and structures do we accelerate the use of effective approaches?
- There is a critical need for teachers who are familiar with computing; training requirements need to be identified.

Possible Programs

- Sponsor revised curricula based on deep computer penetration and use.
- Develop programs which can be used as models for total deployment of resources. For example, assessments of 'centers of excellence' can aid in the planning of more widespread instructional computing programs.
- Promote classroom (design) modifications to accommodate the easier use of new technologies.
- Regional training centers for faculty to exchange information and develop skills in the new technologies.

3 What are the national needs for competency in computing?

- These needs fall into three categories: Educational requirements for quantitative levels of computing; training programs to meet industry's needs; computer literacy for the public.
- Measurements to achieve levels of competency are needed (possibly in terms of terminal hours).
- Efforts are needed both to assess the computer's impacts on society and to teach students about these issues.

- Resources will be needed for fulfilling these training and educational requirements, and the responsibilities of the different parties (government, industry, elementary, secondary, and higher education) need to be understood.

Possible Programs

- Sponsor continuing collection and dissemination of data describing computing in higher education and the needs for industrial training.
- Encourage more interaction between the various parties responsible for training (higher education, government, industry).
- Develop working definitions of computer competency appropriate to the varying needs.

4 Research

- The computer is both a subject of study and a tool of research in all fields. We need to understand what levels of support and what special facilities will be required for furthering science.
- Who should support these facilities, and to what degree? What present Federal policies limit the effective use and penetration of computers?
- Research is needed in the broader information sciences and in the technological impacts on society.

Possible Programs

- Strengthen support by developing more exact estimates for the costs (hardware and software) necessary in order to formulate programs of support.
- Assess the impacts of new uses of office technology (e.g. microcomputers) on research productivity.
- Encourage resource sharing by industry and federal agencies to permit use of specialized resources (CAD/CAM, vector machines) to meet university educational goals.
- Create new large-scale regional resource centers.
- Expand to significant levels the amounts of research into computer impacts on productivity, social changes, policies.

5 How are educational institutions affected by the growth in requirements for administrative computing and its broadening scope as information management?

- The most rapidly increasing area of computer use in higher education is administrative computing. Allocations for computing from total resources, and their effect on educational goals, are pressing issues as ADP comes to have higher priority.
- Universities and colleges need to understand the sources and varieties of demands, especially as they approach issues of automation and improved faculty administrative support.
- Who can afford the improved productivity?

Possible Programs

- Differentiate between the computing needs of administrative and academic applications. (Different kinds of computing are needed for the different constituencies.)
- Sponsor demonstration programs for improvement in productivity (research, administration) through applications of office automation.

6 What can be done to improve the effective use of our national information and computing resources?

- Resources need to be identified, and then the mechanisms which provide incentives and/or limits to sharing need to be studied.
- Computer network or communications support may be required, with the Federal government (and its regulatory agencies) and industry playing important roles.
- National information resources are located in both libraries and computing facilities' data bases; problems of access and integration need addressing.

Possible Programs

- Federal government support for the basic establishment of networks for the exchange of resources.
- Congressional action to facilitate joint efforts and sharing between industry and higher education.
- Support the electronic industries' proposals for incentives to promote research and development.
- Establish a forum for addressing issues which limit resource sharing.

7 What are the organizational and/or structural impacts on higher education?

- Technical changes will impact the structure and organization of the university: the extent to which they will affect faculty, administration, and budgeting is unknown. We need more understanding of how changes in the kinds of instruction (e.g. continuing education, at-home instruction, retraining needs) will affect the structure.
- There should be a clearer picture of how much centralization is needed and how the functions of information management, library computing and computer centers are related.

Possible Programs

- Develop curricula for continuing education, with the aid of professional groups and assessments of national needs. Develop programs to accommodate the displaced.
- Encourage research into the structural impacts on universities' pilot programs to evaluate productivity impact on the uses of terminals by faculty for communication and textual use.

(4) Interaction Through Papers and Conferences

Preliminary results of the study were presented [illegible] of ACM and EDUCOM, for feedback and discussion.

(5) Circulation of the Summary

A summary of the report was circulated widely [illegible] used to guide the development of the final report.

3. BACKGROUND

3.1 Over 15 Years Since the Pierce and Rosser Reports

The Pierce Report provided a general view of computers in higher education which:

(1) Reinforced the belief that computers were important in all of education, not just in a few specialized fields;
(2) Provided a simple measure for expected cost of academic computing ($60/year per *undergraduate* student);
(3) Emphasized the need for interactive computing;
(4) Stressed the need to remedy the computer deficit in undergraduate education by significantly increasing federal support in order to bring the total investment in instructional computing to $414 million in 1972.[1]

The Rosser Report, commissioned in 1962 by the National Academy of Sciences and the National Research Council, emphasized the link between growth in the sciences, engineering, and medicine and the shortage of students trained as computer users.[2] It recommended doubling the amount of computing in higher education between 1964 and 1968 by doubling the federal share of campus computing budgets.

Even though the budget for computing in higher education has increased by more than a factor of six since 1964:

(1) The federal share has declined significantly—contrary to the expectations of the Pierce and Rosser reports; and
(2) There is still a computing education deficit.

3.2 Hamblen's Studies Show Rapid Growth and Declining Federal Support

Dr. John Hamblen conducted four surveys on the use of computers in higher education.[3] These surveys show that expenditures on computing for all applications have grown from $221 million on 1966-67 to $1,301 million in 1980, with the cost per student increasing from $26 to about $135 (Chart 3-1). That does not mean that the Pierce goal of $60 per undergraduate for instructional computing has been reached. Over half the expenditures are for administrative data processing. Chart 3-2 shows that the proportion devoted to administrative data processing has been growing rapidly in the past ten years.

While funding for computing has grown significantly, Hamblen's data show a slight decline in federal dollars (without considering inflation or advances in computing power per dollar). While the amount of federal funds spent on campuses has remained roughly constant at $80 million per year (with no corrections for inflation), the

1. President's Science Advisory Committee. *Computers in Higher Education* (Pierce Report)

2. National Academy of Sciences, National Research Council. *Digital Computer Needs in Universities and Colleges* (Rosser Report).

3. John W. Hamblen. *Computers in Higher Education. Expenditures, Sources of Funds and Utilization for Research and Instruction 1964-65, with Projections for 1968-69*. Atlanta. Southern Regional Education Board, 1967. John W. Hamblen. *Inventory of Computers for U.S. Higher Education 1966 67: Their Utilization and Related Degree Programs*. Washington. GPO. 1970. John W. Hamblen. *Inventory of Computers in U.S. Higher Education 1969 70: Their Utilization and Related Degree Programs*. Washington: GPO. 1972; John W. Hamblen and Thomas B. Baird. *Fourth Inventory. Computers in Higher Education 1976-77*. Princeton: EDUCOM. 1979

percent of federal support has dropped from 28% to 7%. Of course, some additional federal investment is hidden in individual program budgets where computing facilities in the form of mini- and microcomputers are part of laboratory facilities. In general, however, federal expenditures are primarily for research computing in support of federal grants and contracts, and not for support to develop campus computing services.

This low investment is in marked contrast to the capital investment program begun in 1956 to provide seed funds for computer facilities. From the initial grants to Oregon State, MIT, and Carnegie-Mellon the NSF program provided over $70 million through 330 grants to 184 institutions. Since the institutions more than matched the grants, the total investment represented a quarter of a billion dollars.

Chart 3-1.
Computing: Estimated Total Expenditures and Cost Per Student

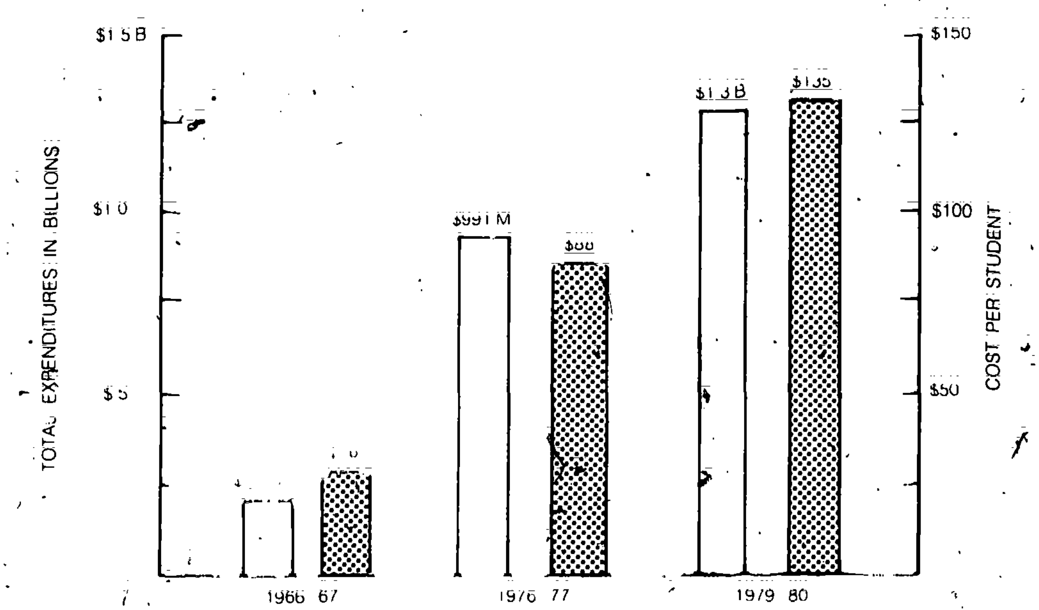
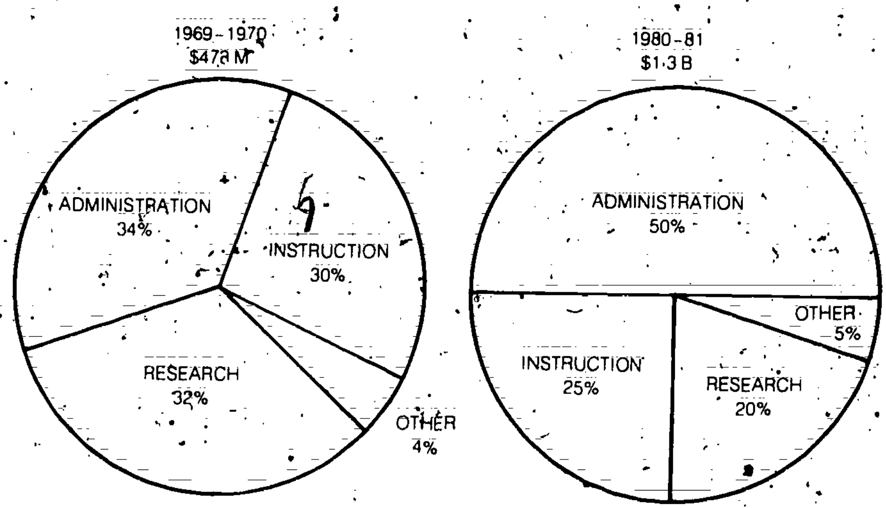


Chart 3-2:
Distribution of Expenditures



Source Hamblen

3.3 Congressional Attention has Focused on the Potential for Improved Productivity in Education

In 1977 the House Subcommittee on Domestic and International Scientific Planning, Analysis, and Cooperation held hearings on the theme of "Computers and the Learning Society." The major objectives were:

(1) To compare achievements in the computer-based education field against past promises;
(2) To examine what technological developments might be expected in the future and what might be an appropriate role for the Federal Government to play.[4]

Testimony and comments were directed to the use of computers in education as tools to improve the learning process—not as scientific instruments or as tools in disciplines. The committee recommendations included directing federally-sponsored research in courseware and instructional theories, sponsoring regional demonstration or test centers, and establishing a Federal Commission to develop goals and to estimate funding requirements.

4. U.S. Congress, House Subcommittee on Scientific Planning, Analysis, and Cooperation Computers and the Learning Society, p. 5.

In October 1979 hearings were held by the Subcommittee on Science, Research, and Technology to discuss HR4326,[5] a bill to create a federal commission to study the scientific and technological implications of information technology in education. Additional hearings were held by the Subcommittee on Science, Research, and Technology and the Subcommittee on Select Education in April 1980.[6] At each of the hearings the question of computing and education broadened to general discussion of the changes in education due to technolgoy.

While no congressional action was taken on any of the recommendations in 1980, there is continuing interest. One example is the current bill to establish personal computing centers for instructional uses around the country.

3.4 New Computing Technologies are Providing New Opportunities

Computer use in higher education has expanded from a narrow base of scientific and administrative applications in the '60s to wide penetration throughout the curriculum today. This evolution also involves a change in the concept of the computer as a machine that calculates to an information-handler that provides a means of transforming information. One example is the availability of text-processing facilities for student use. Text-processing is more than a substitute for a typewriter; it reduces the friction which holds students back from the benefits gained by rewriting their papers. Students are now much more likely to enter into continuous dialogue with their instructors by rewriting after receiving comments.

New instructional opportunities are emerging as computing, communications, and video technologies combine. J. C. R. Licklider said, "The fact that major segments of computer technology and communications technology have in effect merged greatly increases the intrinsic capability of information technology to support education applications."[7] For example, the development of video disks (holding between 50,000-100,000 individually accessible frames—equivalent to the entire Encyclopedia Britannica—in mixtures of sound and video used in combinations under microprocessor control) as instructional aids is just beginning.[8]

The merging of information technologies will also change the function of libraries, for they will become a way to access great stores of information. The library as a method for transmitting and disseminating knowledge existed long before the printing press. However, if we continue to concentrate on books as our major information source, we will miss the true objective of using information effectively. As the publishing industry itself changes (as it has already, due to the xerox process), do all libraries need copies? If the information is computer generated during the printing process, who should have access to the tapes?

5. U.S. Congress, House Subcommittee on Science, Research, and Technology. *Information and Communications Technologies Appropriate in Education (Including H R 4326)*

6. U.S Congress, House Subcommittees on Science, Research, and Technology and on Select Education. *Information Technology in Education*

7. Ibid., p. 97

8. If we assume a relatively stable growth rate in computing power we can expect that computers the [illegible] of today's minis and mainframes will soon be available on chips for a few hundred dollars. (However, the costs of software and peripherals will offset somewhat these dramatically lower hardware costs.) See Licklider in *Technology in Science Education* and Turn, *Computers in the 1980's*.

4. FACTORS: HOW COMPUTING IS AFFECTING HIGHER EDUCATION

4.1 The Structure of Use in Higher Education

The fundamental (but blurring) divisions of computer use in higher education are instruction, research, and administration.

(1) Instruction

Computing ranges from a *subject of study* (computer science and electrical engineering) to a *tool* (statistical and data analysis routines) to an *aid* in the instructional process (computer-aided instruction). Student use of the computer as an information facility is growing as text editing facilities allow students to write and revise papers much more easily. In addition, substantial new student participation is provided through computer simulations to model change and growth.

The most desirable form of instructional computing is with interactive terminals which provide immediate feedback. There are many options for providing this service, ranging from independent microprocessors to intermediate minis to very large time-shared systems. Unfortunately, there is no simple algorithm for selecting the best approach for providing interactive services.

(2) Research

While there is no distinct division between instruction and research (are independent projects and theses research or instruction?), research use of the computer includes both in-the-laboratory use of micro- and minicomputers for control of experiments and acquisition of data and massive (or never enough) computing resources for complex analysis and simulation. Computing options at campuses include independent computers in departments, access to large central facilities, and use through telecommunications networks of facilities at national laboratories, such as the vector machine at the National Center for Atmospheric Research.

(3) Administration

The Fourth Inventory of Computers in Higher Education. An Interpretive Report, based on the Hamblen surveys, shows the following areas for administrative data processing: Admissions and Records, Financial Management Planning, Management and Institutional Research, General Administrative Service, Logistics and Related Services, Auxiliary Service, Financial Aid, Library, Physical Plant Operations and Hospital.[1]

The most striking aspect of administrative computing in higher education is its growth. Over 50% of funding for computing in higher education now goes to administration. This penetration reflects the need for improved productivity in administration, the enlarging options for use of computers, and the increasing demands by state and federal government for information.

4.2 Ways in Which Computing is Changing Higher Education

Before assessing the national issues and their impact on higher education as well as the new opportunities, we will review from a broad perspective the general ways in which computing impacts the educational system.

1. Charles R. Thomas, "Administrative Uses of Computers in Higher Education," in *The Fourth Inventory of Computers in Higher Education. An Interpretive Report.*

In the race towards maximum and efficient use of information resources, computing has arrived at the starting gate with not one but many entries. That is, in the attempt of colleges and universities to provide information services computers have come to play many and varied roles; they affect both what services are offered and how these services are delivered and supported. Computing in education has evolved from a process for contributing to scientific advances (which justified the early NSF capital programs to introduce computing) to a diverse set of information processes.

There are many ways to integrate the three application areas (instruction, research, administration) into one institutional system, as well as many patterns for allocating supporting resources. Nonetheless, most universities pass through evolutionary stages in computing as the use of technology increases.

The penetration of computing generally follows three steps:

(1) Computers are first used as *replacements* for manually performed functions.

(2) They become *tools* for new kinds of tasks as new capabilities for computers are found.

(3) Computers become *structurally integrated* into the system. This occurs (it is beginning to happen at some schools, and will continue to occur at an increasing pace) when computing is perceived as a fundamental element in providing information services, and as such actually changes the structure for providing those services.

As the use of technology diffuses within the educational system, the choices for providing services become more numerous and the process of planning becomes more complex. Even though the number of institutions and students will remain relatively stable over the next few years, computing will be dramatically unstable as use increases to meet the needs of computer literate students and for increased research applications. This instability is heightened because the growth of computing is itself an unstable process, with its change from a high cost, centralized activity to its widespread penetration in the mass market.

At the same time that computing, as an outside influence, penetrates the educational system there are three factors that have a significant impact on how this technology is diffused within higher education. These influences are:

(1) The *support structure* for providing computing resources. Local (state and private) and federal agencies, state boards of education, faculty, professional societies, and administrators all have roles in determining where and how computers are used.

(2) The *level of understanding* and acceptance of computers within an institution. Decisions about how to use computers and what equipment to buy are affected by what people know and by their access to information.

(3) The *computing services* provided. The selection of services (e.g. batch vs. interactive, micros vs. minis) and their support will affect the direction, impact, and rate of diffusion of the new technologies.

4.3 Costs for Higher Education

An estimate of the costs for widespread [illegible] computing can be [illegible]ed using the number of expected terminal hours needed. If the average in [illegible] school across all disciplines is assumed to be 3 hours/student/month, then considering the 9 million students, 27 million hours/month will be required. Currently, these hours could be provided by "midi" systems whose cost is approximately $3/hour including all equipment, phone lines, etc. Thus the instructional support costs (for 9 months of the year) would be about 9 months/year × $3/hour × 27 million hours/month = $729 million/year, which is several times the amount spent on instructional computing today. This estimate does not consider the software costs for curriculum development, so this usage estimate might easily be exceeded.

While technology improvements will help to reduce these costs in the future, the increased software costs needed to match new hardware capabilities may leave the estimate constant. Thus, significant additional resources will be required, to come from either reallocation of current funding or from new funding—student fees, contributions, federal support, etc.

5. LIMITS TO GROWTH

New demands for computer use and training are compelling institutions of higher education to address these basis issues:

- Who will teach computing (both as a subject and as a tool)?
- Where are the curricular materials?
- What equipment and resources are available?

Expectations and demands for increased computer capabilities arise from two sides: from those who will be entering higher education and from those who will employ the college graduates. Universities and colleges will soon be facing a wave of high school students with some computer training who will have high expectations for computing in college. While estimates of the numbers of computers in secondary schools vary widely, Dr. Arthur Luehrmann estimates that over 70,000 computers are now in use, with an additional 50,000 microprocessors to be added in 1981.[1] Many high schools are receiving computers as gifts from PTSA's. These actions show that parents put a high value on computing education (outdistancing in many cases the concern of educators and legislators).

The following sections address some major factors that will limit the growth of computing in higher education other than the need for funds to acquire computers.

5.1 Personnel Projections Reveal Severe Problems in the Computing Field

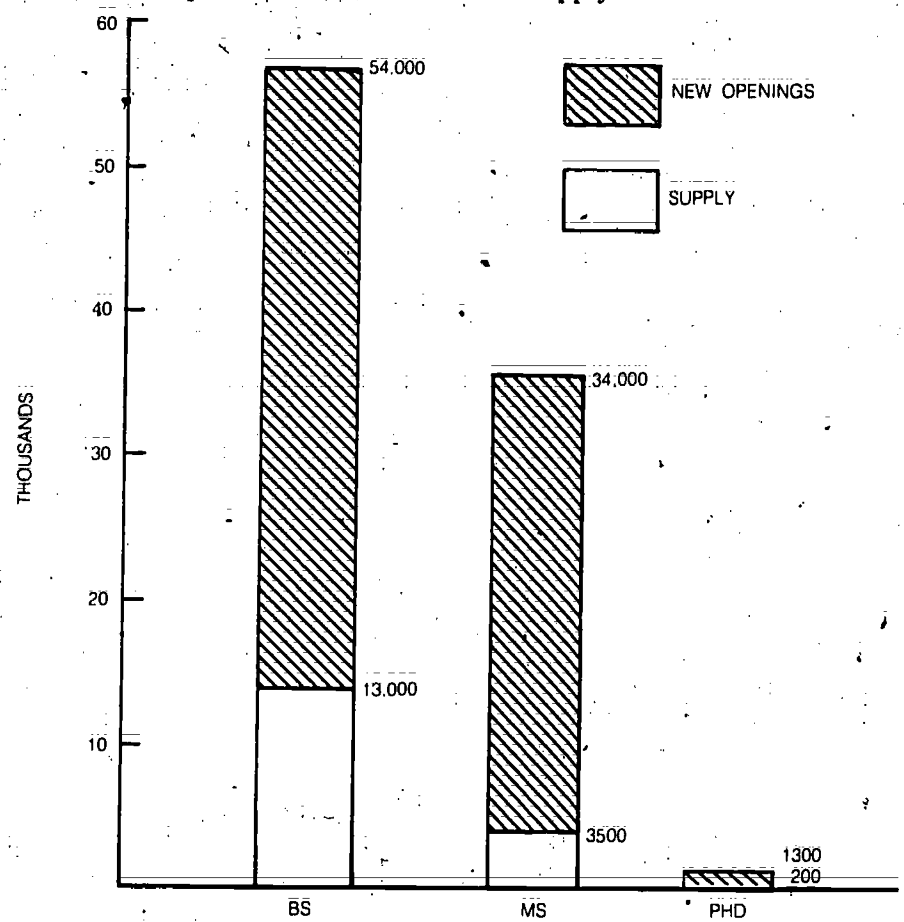
All projections of the need for computer scientists and computing professionals show that the U.S. production of these specialists (and of the teachers needed to train them) is woefully out of balance. Chart 5-1 shows that the need for computer science graduates is out of balance by a factor of ten at the Master's and Ph.D. levels. Not only have enrollments in computing classes soared, but schools are finding that their ability to respond to these needs is blocked by rapidly climbing salaries and the attractions of industrial and federal research laboratories with up-to-date equipment.

The Bureau of Labor Statistics estimates that by 1990 the general need for computer professionals will exceed the supply by a factor of three.[2] The recent report to President Carter by the Secretary of Education and the Director of the National Science Foundation on the condition of science and engineering education in the United States highlighted both the low science education in the United States compared to other countries and our increased needs for the future. The report revealed that the problem is particularly severe in computer science.[3]

The Snowbird Conference of Computer Science Department Chairmen and papers such as the Feldman Report have focused on the capital investments needed per faculty member to support the requisite research facilities. The capital investment required for a high-quality research program is estimated to be over $50,000 for each faculty member.[4]

1. Private communication, based on estimates from manufacturers.
2. U.S. Bureau of Labor Statistics, *Occupational Projections and Training Data*, 1978 ed., Bulletin 2020, Washington: GPO, 1979.
3. *Science and Engineering Education for the 1980's and Beyond.*
4. "A Discipline in Crisis: A Report," p. 8.

Chart 5-1.
Computer Science: Demand and Supply 1979



Source Hamblen, *Computer Manpower—Supply and Demand by States*, 4th ed. p 14

5.2 Instructional Material

The development and evaluation of good curricular materials are particularly important when computers are used in instruction. Since the time required to develop computer-aided instructional material may take from 100 to 1,000 hours per terminal hour, serious limitations are placed on an instructor's time. Furthermore, incentives for faculty members to develop computing curricula are few; in tenure decisions the development of these materials is not always considered important. In addition, questions of ownership, patent, copyright, and distribution affect the financial incentives. It will take years before these issues are as well resolved as the principles of author's rights in book publishing.

5.3 Training and Retraining

The penetration of computing in all disciplines is very much affected by the training (or time to learn) available to faculty members. Since the best incentive for learning is normally peer pressure we can see that new techniques evolve more in fields where the application of computers is direct, such as in the physical sciences. Change in other disciplines proceeds more slowly and is more directly affected by the opportunities for faculty members to receive training and release time to restructure their courses.

The current high number of tenured faculty in many fields means that the younger instructors who could be the source of greater innovation may not be able to find positions. Thus, strategies for retraining should be even more important. Teacher colleges also will need to place a higher priority on computing so that new instructors will be prepared to meet the demands of the growing number of computer-literate students.

5.4 Resources and Allocation

Introducing computing into new areas of higher education is more than acquiring computers. The need for more telephone lines, networks, building modifications, and new classrooms will initiate significant conflicts over scarce resources. Additional space, which may be as important as new funds, is already at a premium in most universities. Indeed, space is often more difficult to obtain than funds because of the long lead times and the difficulty of rewiring classrooms for telephone access.

The allocation problem for computing on many campuses is exacerbated by the conflicts over resources between administrative and academic computing. Unfortunately, the decision makers on a campus can see more directly the demands for, and the result of, improved administrative services; academic, particularly instructional, needs are rarely able to reach the same level of priority.

The problem is partly a budgeting and planning issue. For example, the library will often apply formulas for establishing base budgets based on the numbers of students and other factors. Few formulas exist today for allocating computing funds. This often results in the budgeting process being directed by the computer center director rather than proceeding from the Deans or other appropriate budgeting units.

In large universities academic computing (often stimulated initially by NSF capital grants) is usually centralized in large facilities operated on a self-sustaining basis. In the past, federal grants and contracts have been major supporters of these facilities, with economies of scale providing significant advantages to all users. However, advances in technology towards more mini- and microcomputers have made economy of scale less of an issue. Furthermore, the funding structures of federal agencies provide greater incentives for investigators to purchase individual equipment rather than to share resources. Researchers are more likely to desire capital purchases because of the continued availability of the equipment at the conclusion of a grant and the uncertainty of obtaining operating funds for shared equipment, even though the costs of supporting an independent system (software, maintenance, systems support) are significant. Thus the prospects for long-term support for large academic centers will grow more dependent on funding sources other than the federal government. At the same time, however, the prospects of large centers as the most effective way to deliver computing services will diminish as the technology advances and the costs drop. The critical issue will be transition—how to change without significantly degrading the critical factors of stability and continuity.

6. FINDINGS

6.1 National Goals

The national needs for increased productivity and trade will be increasingly dependent upon technology. Concern over antiquated facilities in certain key U.S. industries (such as steel and auto) directly forges a link between computing, education, and national goals. However, this link (which includes providing resources to higher education to aid in the transition to the information society) is weakly forged in the United States.

Other nations have identified their needs for transforming their economies by accelerating the influences of computers and communications. They have identified national goals through studies and plans. Japan developed a plan in 1972 to accelerate its transition to an information society. This ambitious plan (which called for an investment of $53 billion dollars) recommended a wide range of research and development activities, from communications research to experiments with "wired cities" (where access to data bases, education, and messages would be available in every home).[1]

France developed a "Plan Telematique" based on the Nora Report which forecast the issues challenging France's economic and social development that would require coordinated investment to solve.[2] Two significant steps have been taken:

(1) Every high school in France will have one or more microprocessors and access to high quality instructional material.

(2) Instead of telephone directories, there will be video display terminals for each telephone subscriber; these terminals will also provide access to many other services.

The United States has not developed broad plans or studies which address the problems of national goals and which would show the links between opportunities, investment, and outcome.

In particular, the role of higher education in meeting new and increased demands for information has not been considered. Schools, colleges, and libraries have long been the major providers of knowledge to society. However, the information technologies are providing new opportunities for large corporations and foundations to compete directly with these traditional institutions in satisfying the ever-growing needs for information. If colleges and universities are to remain viable as custodians and transmitters of knowledge they must be prepared to use the new technologies to transform their current educational processes.

6.2 Computer Competency is Needed

The transition to the information society is overtaking many of our citizens' ability to absorb information. In fact, Japanese scholars have proposed a measure for "information pollution."[3] While the newest developments in microprocessors will become

1. Japan Computer Usage Development Institute. *The Plan for an Information Society: A Year 2000 Japanese National Goal.*

2. Simon Nora and Alain Minc, *The Computerization of Society.* See also Jacques Hebenstreit, "10,000 Microcomputers for French High Schools," in Computer 13(7):17-21.

3. Youichi Ito, "The 'Johoka Shakai' Approach to the Study of Communication in Japan," in *KEIO Communication Review* 1(1): 13-40; *Information Societies: Comparing the Japanese and American Experiences,* Alex S. Edelstein et al. eds., Seattle: International Communication Center, University of Washington, 1978.

as pervasive as digital calculators, because of the general decline in literacy as measured by college board tests and the level of capability in army recruits (the latest plans are for developing armed services repair and maintenance manuals in comic book form!) we need to address:

(1) The role of the educational system in computer instruction (and the role of higher education in particular in assuring computer-literate graduates);
(2) The relationships and cooperation of university and industry in meeting national requirements for technological growth; and
(3) The level of computer literacy needed for the public.

6.3 New Objectives in Resource Sharing

While higher education has always had a significant amount of resource sharing (research libraries, joint courses, physical plants), the rapid pace of change and the difficulty of continuing to support the capital needs for research and instructional facilities will necessitate new approaches. There will be a new emphasis on sharing information (data bases and software) rather than sharing computer power. Issues of *access, standardization* and *cooperation* need addressing, particularly as information resources cause the functions of libraries and university data bases to merge. Efforts like CONDUIT (software sharing) and EDUNET (a facilitating network for access to a variety of university computing resources) will need to be emulated or expanded. For example, industry may be able to provide access to specialized resources for instruction and research use (e.g. computer-aided design and manufacturing facilities), but encouragement is needed through tax incentives and new treatment for equipment donations.

6.4 Structural Changes Needed

The structure of higher education, while traditionally resistant to innovation, will be dramatically affected by the changes brought by information technologies. Previously stable campus organizations will be challenged by innovations which affect the basic assumptions that govern them. For instance, today the library, printing plant, mail service, and computer facility see themselves as providing very different services. However, the introduction of electronic mail, the access to bibliographic information through terminals, and the computer composition of text ready for printing all challenge current assumptions of organizational separation.

These services are all concerned with the transformation and distribution of information. Organizational focuses will shift more towards the fundamental task of moving information through networks. Joint planning will be needed to avoid unnecessary duplication and uncoordinated standards. Information technologies are a catalyst for organizational change because they alter the framework for producing and transmitting knowledge, a basic function of higher education.

6.5 Opportunities in Instruction

Information technologies will affect instructional opportunities in two major ways.

(1) The current primary instructional formats (lectures, discussions, experiments, papers) will be augmented and supplemented by computer usage. Low cost, high quality course material on video disks will greatly expand today's video techniques. Access to sophisticated computer-aided instructional facilities such as PLATO will rapidly increase as the new low-cost microprocessor terminals reduce the costs of, and the dependence on, communications.

(2) Access to education—today obtained by being on campus or by using limited T.V. access—will change significantly when the average student has a portable terminal/display/microprocessor to access material, to submit papers, and to communicate with instructors and other students.

The notion and nature of continuing education will change when students and faculty have greatly expanded options for remote communication. "Teletext" facilities (cable and T.V. access to information) will open new directions for satisfying the rising demands for instruction, and home access to course material will provide new opportunities for continuing education.

6.6. Support for Computing Research

Budgetary pressures in higher education in conjunction with the high cost and brief life span of state-of-the-art equipment will stimulate new approaches for developing cooperative research. Consortiums between universities and industry will become far more frequent as ways to tackle mutual research and educational issues. Rapid advances in information technology are placing additional burdens on both the public and private sectors. Developments in microelectronics which stimulate the re-engineering of manufacturing equipment and control machinery place new demands on engineering and computer science programs. In addition, the new emphasis on information management in business creates a high demand for people with both business and computing experience and for new research in computer applications and the decision sciences.

While industrial and state government support for research in universities may increase substantially, a strong role for the federal government is still required, particularly in areas relating to national interests (to support defense and to maintain the U.S. technological lead in computing and electronics). In the same way that research facilities in physics are now supported as national resources, it will be important for the federal government to fund advanced computer research laboratories that cannot be maintained by a single state or university.

7. STRATEGIES AND RECOMMENDATIONS FOR NATIONAL ACTION

7.1 Reasons for National Action

We could argue that, since computing in higher education has had little federal support during this recent period of great change, there is no need for national actions today. However, the initial growth of computing was significantly stimulated by federal programs (the capital program in the '60's for acquisition, the network programs, and support in computer science and science education by NSF). These investments may be judged a remarkable success: the handful of colleges with computers in the '60's has grown to almost 100% of schools today; entire industries were born based on university research and timesharing networks.

The results of this study's survey of the issues and the meeting of the Consensus Panel revealed wide agreement on the issues facing the nation and higher education in the transition to an information society.[1]

- Other nations are developing highly integrated plans for accelerating their transition to information-based economies through joint efforts of industry, government, and education.
- Increased productivity and trade will be closely linked to our ability to apply the results of new developments in microelectronics, computing, and communications.
- The United States faces a critical shortage of people educated to use these new tools and, in turn, higher education faces severe resource problems (faculty and facilities) in responding to these national needs.
- Industry and government are concerned with these issues and are supportive of the development of strategies to improve our national position.

7.2 The Information Society and Higher Education

In what ways does the change from an industrial society to an information society require a new role for higher education?

Institutions of higher education will be called upon to provide greater opportunity for life-long learning and for retraining to meet the needs of new technological developments. Increased public awareness of, and ability to use, computers will compel schools to incorporate new technologies in their services; and greater emphasis on the storage, retrieval, and dissemination of information will lead research and library activities towards developments which make information more useful to science, technology, and the advancement of knowledge.

What new opportunities does the merger of microelectronics and communications provide for higher education?

The broader base of users and the greater number of computers create the potential for dramatically lower software costs; lower costs in turn further increase access throughout a school, with more computers and individual terminals for student use. Greater emphasis on individual computers/terminals and decentralized systems will

1. These statements were developed in conjunction with the Consensus Panel and Steering Committee.

permit greater flexibility in instruction (e.g. by the merging of computers and video-disks). Advances in communications will contribute to more distributed education systems that provide greater opportunity for learning at home and other places off campus, and will allow increased access to national networks for more resource sharing.

What effects will the "information explosion" and new technologies for storing, retrieving, and distributing information have on higher education?

New concepts of information sharing are emerging: a blurring of the distinction between computer centers, resource centers, and libraries; greater interdependence, with resource sharing and shared collection development; and increased dissemination of information outside of educational institutions for more productive use by the public and private sectors. These developments will require substantial capital investments. In addition, resources will be needed to convert libraries to more efficient storage and retrieval systems. In order to accommodate increased private sector involvement in information services (e.g. in developing data bases and converting documents into microforms), institutions will have to develop new policies for information storage and dissemination.

How have other nations used higher education to advance their national information policies?

Other nations have recognized the role of computing in the development of their national plans and are investing in research and training with a focus and on a scale not found in the United States (e.g. vector computers for university research in Germany, Denmark, and Great Britian; programs to place microcomputers in all French high schools). Japan has set ambitious national goals for an information society and for leadership in electronics through coordinated efforts requiring cooperation between business and education; and Canada has considered higher education in planning telecommunications and economic policies (including participation in a national information network).

What are the critical areas requiring national support?

Federal and state governments and industry need to provide support and direction:

(1) To encourage resource sharing (e.g. software, data bases) in an environment characterized by the high cost of software and the low cost of hardware;

(2) To develop, evaluate, and disseminate curricula and new approaches for using computers in instruction;

(3) To provide computer resources for research activities that require large-scale investment (e.g. VLSI development);

(4) To support research and development in order to respond to national information needs and to maintain U.S. leadership in technology and communications.

7.3 Strategic Recommendations

Any attack on the national issues will require participation by a number of constituencies—industry, federal and state government, higher education, associations, and societies. However, in order to act we must have a focus for action. The focal point should already be charged with leadership responsibilities in research and education. Thus we propose that the National Science Board take the responsibility for establishing a commission to involve professional, industrial, educational, and government groups in a series of activities focusing on the issues surrounding computing in higher education. The tasks should include, but not be limited to:

- Identifying policy issues for Congress and federal agencies
- Informing the public about issues
- Stimulating curriculum development
- Identifying new strategies for human resource development, particularly to ensure the equality of opportunity
- Expanding research programs
- Coordinating the development of standards for computing in higher education

The commission, in carrying out the above responsibilities, should work closely with representatives from:

Industry

- To develop long-range projections of human resource needs in computing and technological fields
- To work with universities to share unique resources, including industrial/academic staff exchanges and fellowship support
- To encourage the development of joint research projects with universities

Universities

- To develop priorities and plans for providing the computing environment needed for education and research
- To pursue vigorously the sharing of computing and information resources and curricular materials, both on campus and among institutions
- To develop more efficient mechanisms for transferring technology from universities to other elements of society
- To improve the mechanisms for continuing education in computing
- To initiate appropriate shared research activities with industry

Congress

- To allocate the resources for programs identified that support national needs in computing
- To establish coordinated national information policies
- To develop incentives for resource sharing between industry and higher education, and among educational institutions
- To encourage the development of regulations and tax laws favorable to research cooperation and shared development (e.g. patent and copyright)
- To recognize computing as an essential national need and computing in higher education as a national resource

National Science Foundation

- To recognize computing as a fundamental component of science and technology and to focus the currently fragmented programs within the Foundation
- To promote and support programs for developing, assessing, and disseminating curricular materials
- To support national resource sharing and cooperative approaches
- To support the needs of computer science and information science, recognizing these as laboratory sciences with special requirements for human resource development and for equipment

The Executive Branch

- To strengthen science and information policies, recognizing the importance of computing as a national resource
- To continue efforts to create an environment in which education and research, particularly in computing, can flourish with a minimum of constraints and regulations

Professional Groups and Associations

- To serve as a catalyst for initiating cooperative programs among industry, higher education, and government in achieving the goals outlined above

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APPENDIX A

A CONSENSUS STATEMENT: THE PANEL ON COMPUTING AND HIGHER EDUCATION

Dr. Irving Shain, Chairman

March 30, 1981
National Science Foundation

**The views expressed herein do not necessarily reflect the views of the National Science Foundation.

INTRODUCTION

"After growing wildly for years, the field of computing now appears to be approaching its infancy."

—Pierce Report, 1967

Computing in higher education continues to grow wildly, and is still approaching infancy. Today over 2% of the higher education budget is devoted to computing—one billion dollars a year. Yet with the rapid penetration of computers in society, there will be the need to devote an even greater share of the resources of higher education to computing.

The resources needed, the traumas of reallocating already slim resources, and the complexity of transition, with a wide variety of options (microprocessors, networks, computer-aided instruction, administrative growth) pose both problems and opportunities.

The purpose of this panel is to call attention to the importance of computing to national and educational goals and to recommend actions to strengthen the role of computing as the United States becomes an Information Society. By obtaining a consensus we are emphasizing the need for cooperation and sharing among institutions of higher education, the federal government, and the business and industrial sectors.

Our framework for recommending programs and policies to address these issues at the national level is the recent study, "Computing and Higher Education: An Accidental Revolution." This report focuses on the growing use of computers in education and identifies the major national issues which affect their uses in higher education.

- Just as today it is assumed that every student has access to a library, so by the end of the '80's every student will be expected to have access to a full range of computing and information services.
- The mass production of "home computers" will provide each student with an inexpensive computer/terminal by the end of the decade.
- Universities must respond to these rapid technological changes in order to maintain the relevance and quality of education, to improve productivity, and to take full advantage of the new opportunities.

The Information Society

The United States is rapidly transforming from an economy based on industrial production to one based on the transfer of information. Computers are now used in all aspects of daily life to improve the fuel economy of cars and homes and to provide more efficient services. These changes, along with the merging of communications and computers, are causing the emergence of an information-based economy—the transition from an industrial to an information society.

Information is clearly the dominant national commodity, with approximately one-half the labor force holding information-related jobs, and earning over one-half the labor income. The Porat study and Department of Commerce statistics show that information activities now account for over 46% of the GNP. The importance of information technology to the economy is emphasized by the fact that in the sale of computers there is now a balance of trade surplus estimated to be $6 billion.

Productivity and Computing

Advances in microelectronics and telecommunications create opportunities for greater productivity, more efficient use of energy, increased exports, and access to a great diversity of information and educational resources. It is important that the United States maintain its lead in the information technology fields, particularly because computers offer a major opportunity for improving productivity. For example, in industry they provide savings in time and effort through computer-aided design and manufacturing (savings as great as 50:1); in education and training through computer-managed and computer-aided instruction; and in business through managing information activities with terminals and data bases. These computing developments are dependent upon advancements in training and research—areas in which higher education has always played an important role.

The lead which the U.S. has always had in technology is now threatened by the significant investments which other nations are making in research, development, and education. Efforts must be made to increase productivity, through re-investment in *facilities*, through significant *new applications* (e.g. through office automation and computer-aided design and manufacturing,) and through *training* and re-training. In addition, national defense needs call for developing sophisticated information technologies and well-trained personnel.

Higher Education

This Consensus Meeting calls attention to the role which higher education will need to play in the transition from an industrial to an information-based economy. National needs for increased productivity and a literate and well-trained populace increase demands for relevant education and new educational approaches. Higher education must make significant changes in order to respond to these demands through reallocating funds, generating new capital, and developing innovative educational approaches.

There is a major crisis in training computer scientists. There is a lack of support to graduate students which leads to a shortage of faculty. New capital is also required for the equipment to support these needs. Already there is a crisis in computer science—the faculty needed to teach the growing numbers of students are preferring to enter industry in order to have access to up-to-date research facilities. This results in the two-fold problem of not enough graduates with advanced degrees and not enough faculty to provide computing education.

In the following consensus statement we consider specific issues concerning the role of computing in higher education and recommend actions to strengthen the contribution of higher education to national goals.

A CONSENSUS STATEMENT: THE PANEL ON COMPUTING AND HIGHER EDUCATION

1. What is the role of computing in higher education?

(a) Supports training in the use of the computer in research, instruction, business, and all segments of the public and private sectors

(b) Provides a technological base of people, facilities, and kno[illegible]vities

(c) Increases access to information, both within the [illegible]ty and in the nation

(d) Provides a tool in teaching and administration

(e) Develops applications for computers which contribute to the advancement of society

2. In what ways does the change from an industrial society to an information society, in which a majority of the workforce is involved with information-handling activities, require a new role for higher education?

(a) Opportunities for life-long learning

(b) Re-training for new technological developments

(c) Public awareness of, and ability to use, computers

(d) Greater emphasis on the storage, retrieval, and dissemination of information to make it most useful to science, technology, and the advancement of knowledge, and to improve the national quality of life

3. What new opportunities does the merger of microelectronics and communications provide for higher education?

(a) Lower costs allow broader use: greater access throughout the university and more individual terminals and computers for student use

(b) More emphasis on individual computers/terminals and decentralized systems permits greater flexibility in instruction (for example, the merging of computers and videodisks)

(c) Access to national networks provides more resource sharing

(d) The broader base of users, and the greater number of computers create the potential for dramatically lower software costs

(e) Distributed education systems provide the opportunity for education at home and other places off campus

4. What effects will the "information explosion" and new technologies for storing, retrieving, and distributing information have on higher education?

(a) New concepts of information sharing:

1. Blurring of the distinction between computer centers, resource centers, and libraries
2. Greater interdependence, with resource sharing and shared collection development
3. Increased dissemination of information outside of educational institutions for more productive use by the public and private sectors

These developments will require substantial capital investments.

(b) Increased allocation of resources to convert libraries to more efficient storage and retrieval systems (which may be provided through national networks)

(c) New policies to accommodate private sector involvement in information services (e.g. developing data bases or converting documents into microforms)

5. How have other nations used higher education to advance their national information policies?

(a) Other nations have recognized the role of computing in the development of their national plans and are investing in research and training with a focus and on a scale not found in the U.S. (e.g. vector computers for university research use in Germany, Denmark, and Great Britain; programs to place microcomputers in all French high schools)

(b) Japan has set ambitious national goals for an information society and for leadership in electronics through coordinated efforts requiring cooperation between business and education

(c) Canada has considered higher education in planning telecommunications and economic policies (including participation in a national information network)

6. What are the critical areas requiring national support?

Federal and state governments and industry need to provide support and direction to:

(a) Encourage resource sharing (e.g. software, data bases) in an environment which is characterized by the high cost of software and the low cost of hardware

(b) Develop, evaluate, and disseminate curricula and new approaches for using computers in instruction

(c) Provide computer resources for research activities which require large-scale investment (e.g. VLSI development)

(d) Support R&D in order to respond to national information needs and to maintain U.S. leadership in technology and communications

CONSENSUS ISSUES: STRATEGIC RECOMMENDATIONS

The basic step needed to achieve the goals of improving national productivity through computing in higher education and enhancing the quality and effectiveness of higher education is for the National Science Board to create a commission to work with professional, industrial, educational and government groups to develop cooperative programs for supporting computing in higher education. The programs should include, but not be limited to:

- Identifying policy issues for Congress and federal agencies
- Informing the public about issues
- Stimulating curriculum development
- Identifying new strategies for human resource development, particularly to assure the equality of opportunity
- Expanding research programs
- Coordinating the development of standards for computing in higher education

The commission, in carrying out the above responsibilities, shall work closely with representatives from:

Industry

- To develop long-range projections of human resource needs in computing and technological fields
- To work with universities to share unique resources including industrial/academic staff exchanges and fellowship support
- To encourage the development of joint research projects with universities

Universities

- To develop priorities and plans for providing the computing environment needed for education and research
- To pursue vigorously the sharing of computing and information resources and curricular materials, both on campus and among institutions
- To develop more efficient mechanisms for the transfer of technology from universities to other elements of society
- To improve the mechanisms for continuing education in computing
- To initiate appropriate shared research activities with industry

Congress

- To allocate the resources for programs identified which support national needs in computing
- To establish coordinated national information policies
- To develop incentives for resource sharing between industry and higher education, and among educational institutions
- To encourage the development of regulations and tax laws favorable to research cooperation and shared development (patent, copyright)
- To recognize computing as an essential national need and computing in higher education as a national resource

National Science Foundation

- To recognize computing as a fundamental component of science and technology, and to focus the currently fragmented programs within the Foundation
- To promote and support programs for developing, assessing and disseminating curricular materials
- To support national resource sharing and cooperative approaches
- To support the needs of computer science and information science, recognizing these as laboratory sciences with special requirements for human resource development and equipment

The Executive Branch

- To strengthen science and information policies, recognizing the importance of computing as a national resource
- To continue efforts to create an environment in which education and research, particularly in computing, can flourish with a minimum of constraints and regulations

Professional Groups and Associations

- To serve as a catalyst in initiating cooperative programs among industry, higher education and government in achieving the goals outlined above

APPENDIX B

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